Development Of All-Solid-State Sensors for Measurement of Nitric Oxide and Ammonia Concentrations by Optical Absorption in Particulate-laden Combustion Exhaust Streams

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- Thomas Anderson, Robert Lucht (Purdue University)

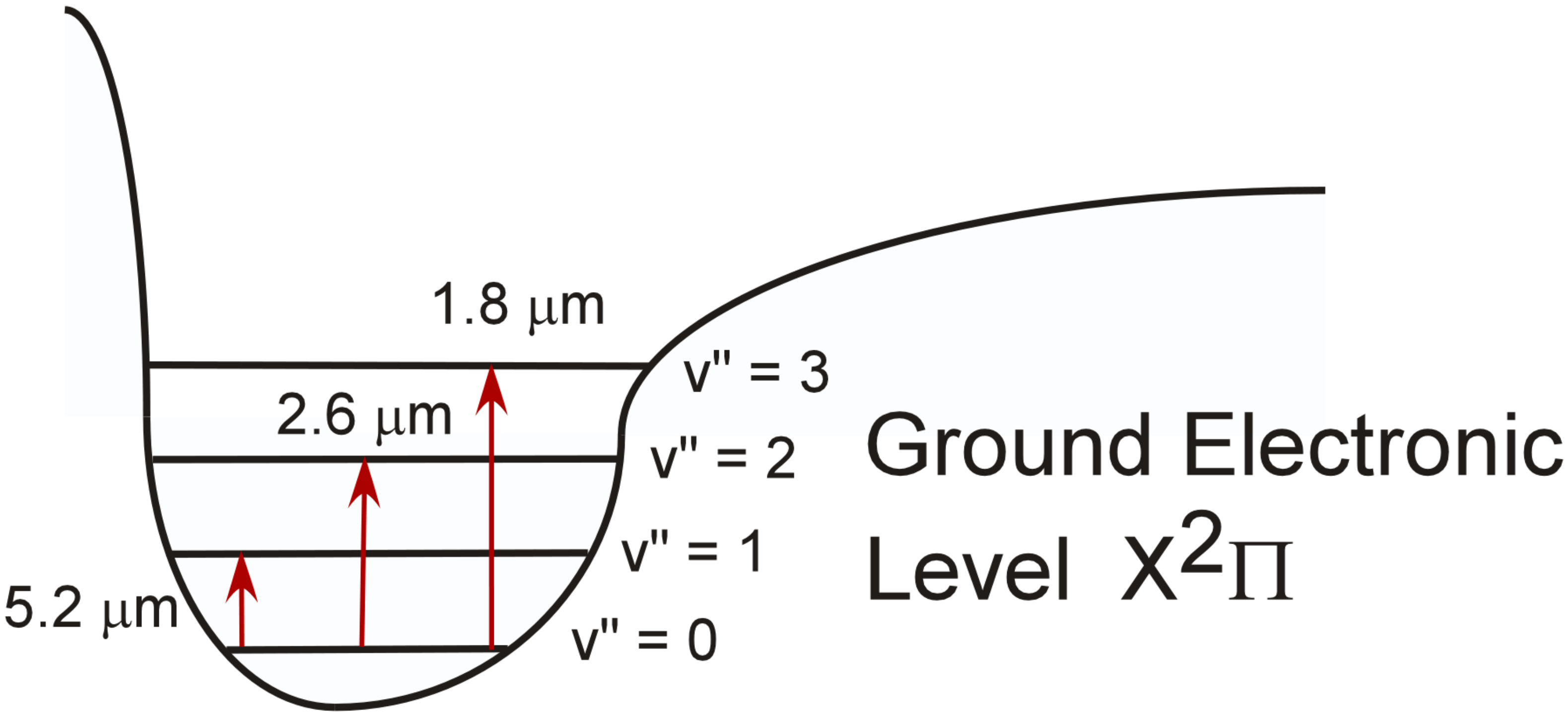
Outline of the Presentation

- Introduction and Motivation
- Diode-Lased-Based Sensors
- Laboratory Gas Cell Measurements
- Field Demonstrations:
  - -APU Gas Turbine at Honeywell
  - -Coal Combustor at Texas A&M
- Conclusions and Future Work

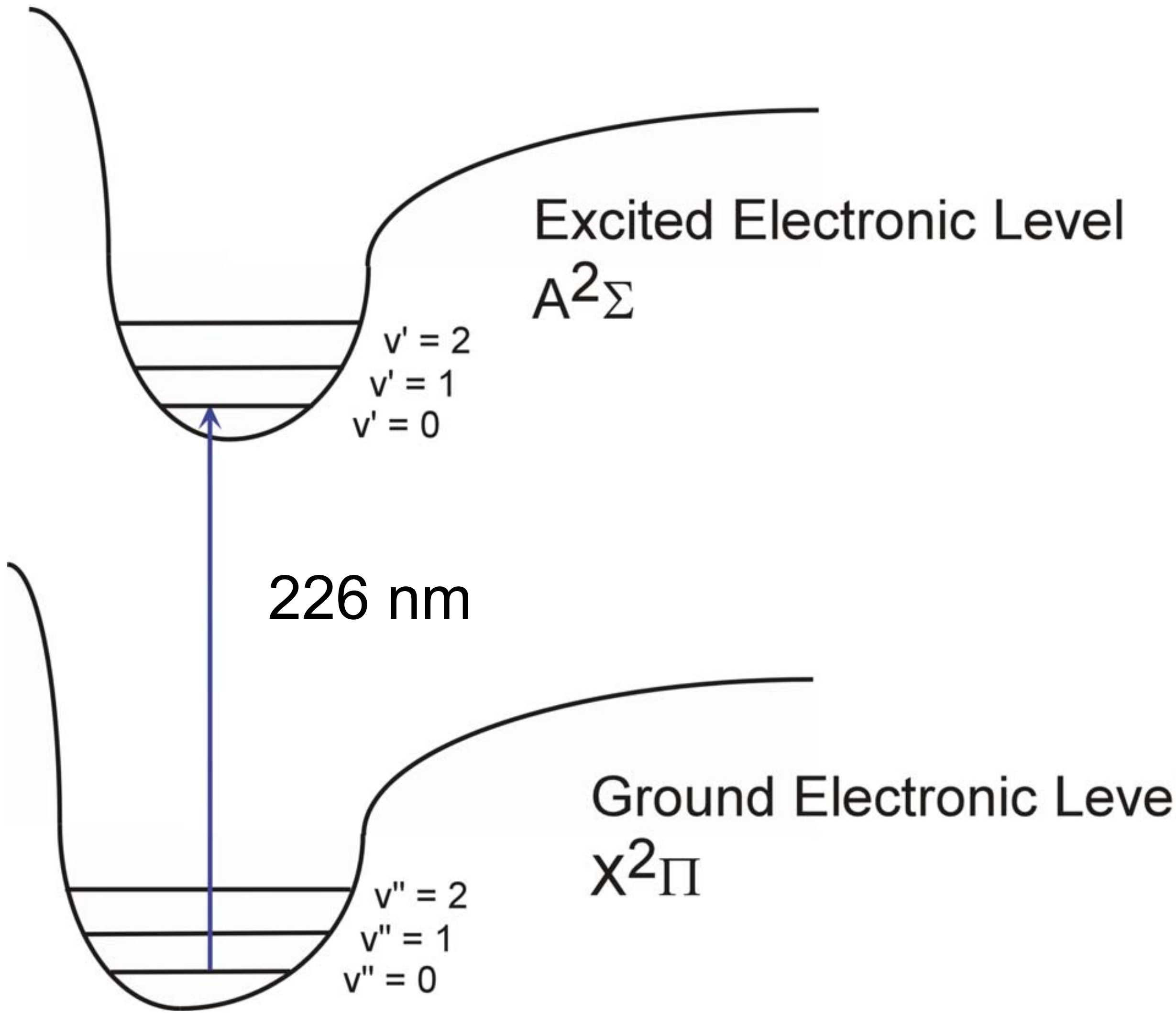
Motivation for the Work

- Optical absorption sensors have the capability of in-situ, real-time measurements of NO and NH_3, potential for incorporation into combustor control systems
- NO absorption band in ultraviolet at 226 nm, fundamental NH3 band at 3 microns are very strong, sub-ppm sensitivity achievable for high-resolution absorption measurements.
- Recent advances in laser technology make development of high-resolution ultraviolet sensor systems feasible, much development also in mid-infrared.

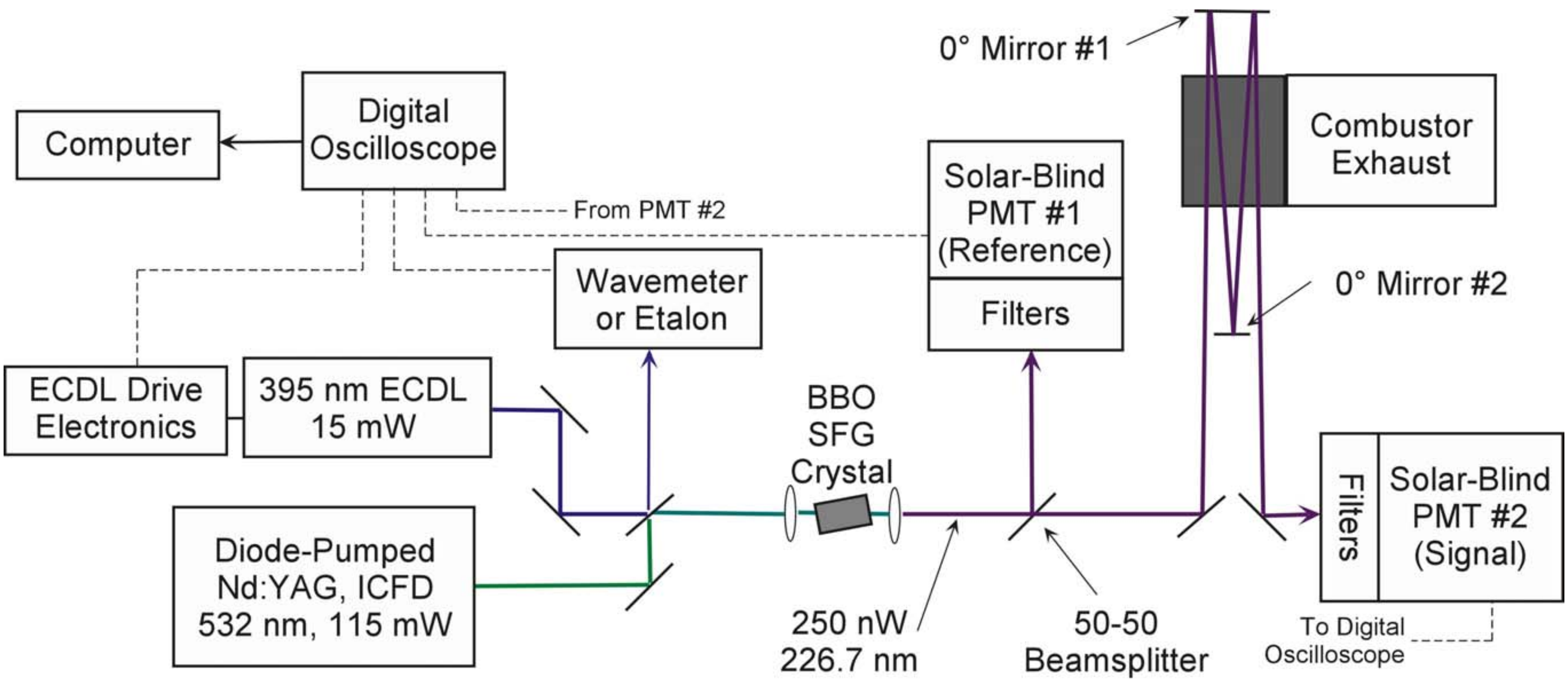
NO Infrared Absorption



NO Ultraviolet Absorption



NO Sensor System



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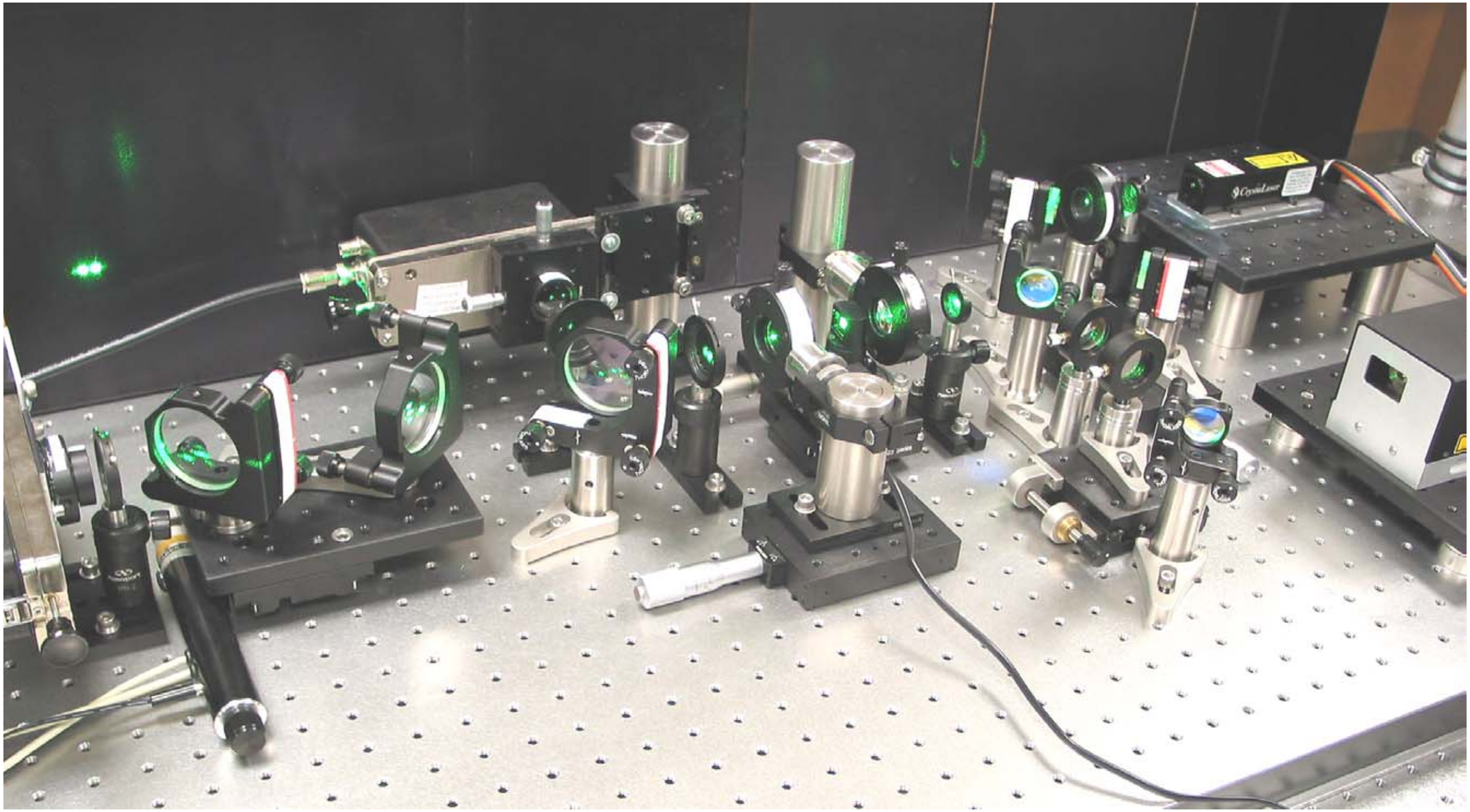
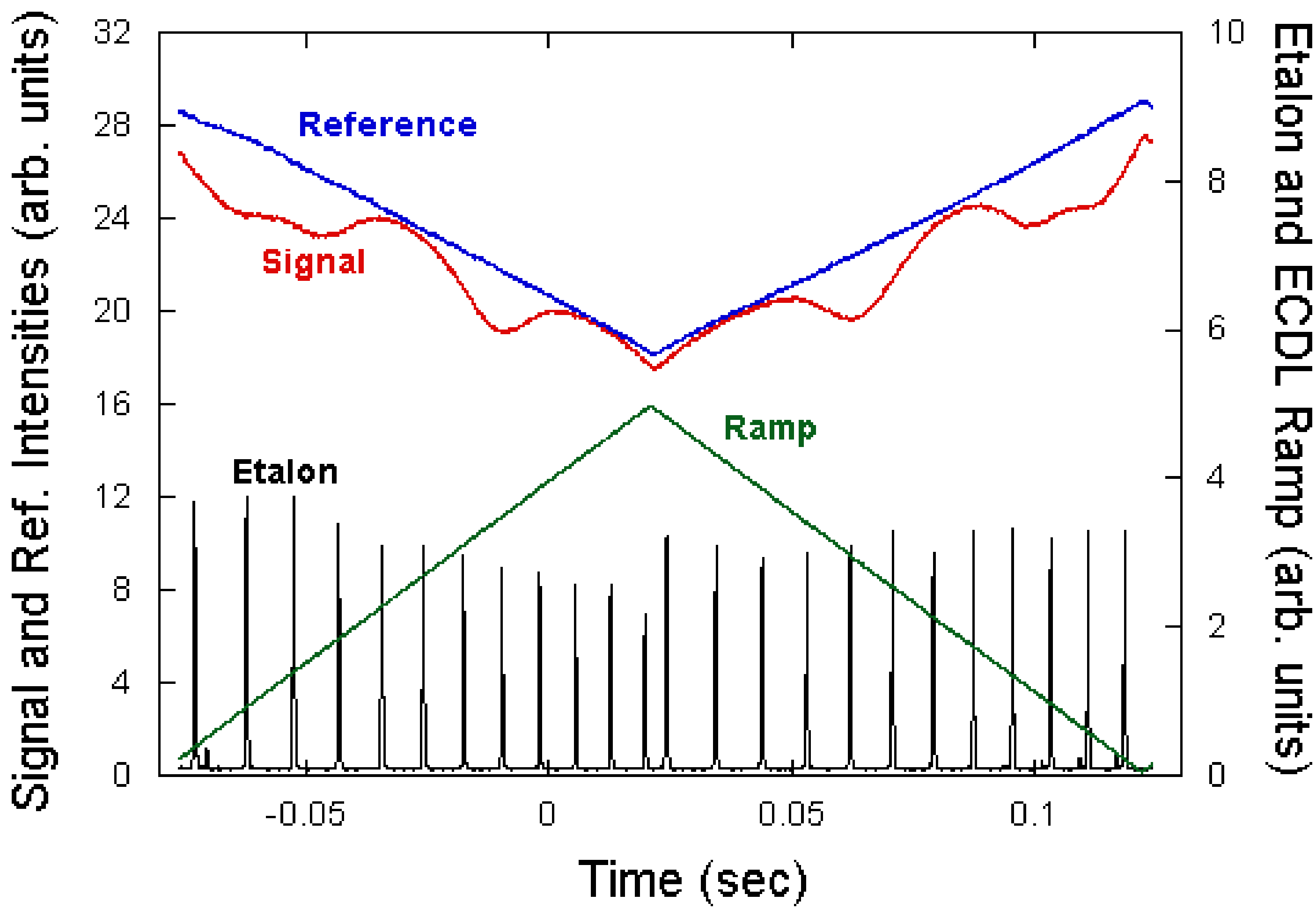
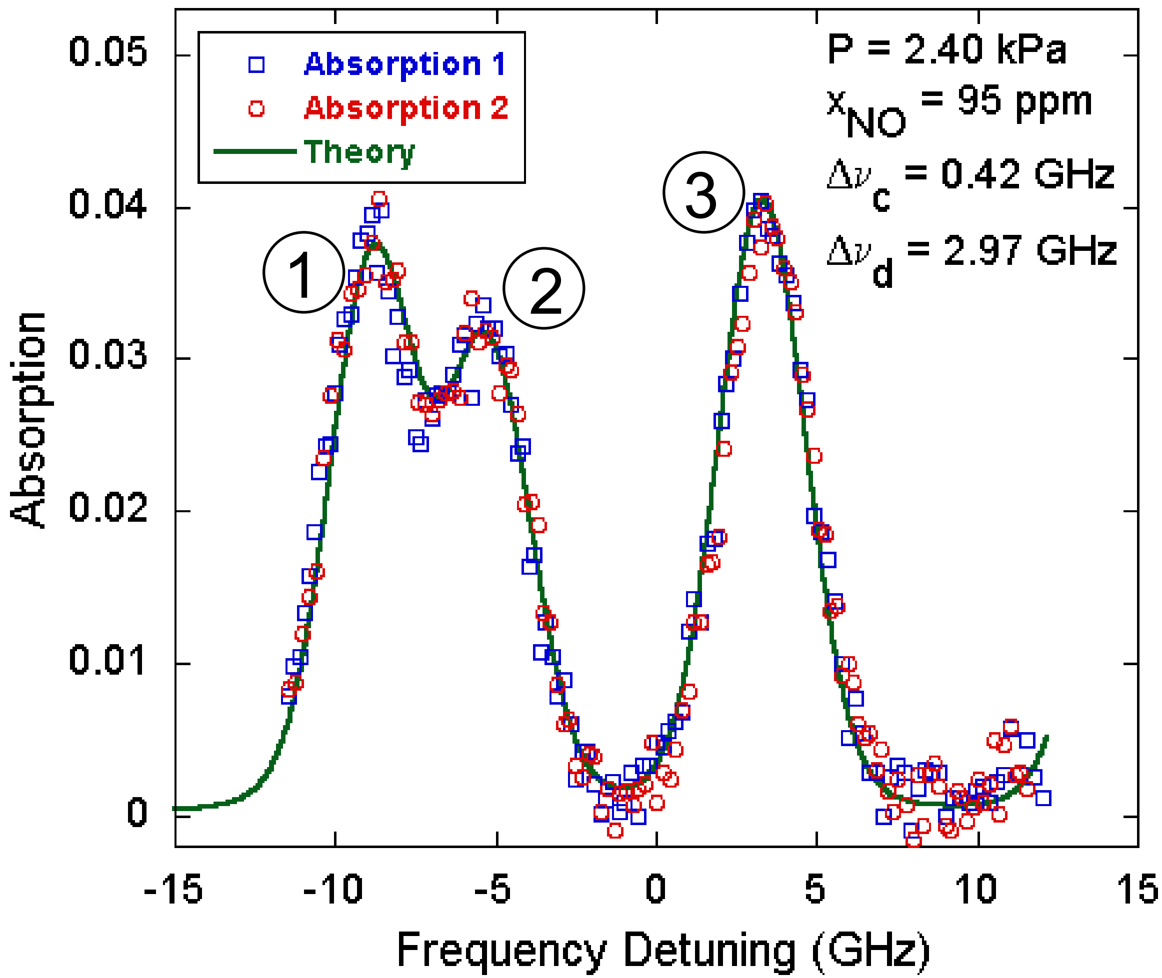


Signal and Reference Beams: 100 ppm NO in Gas Cell

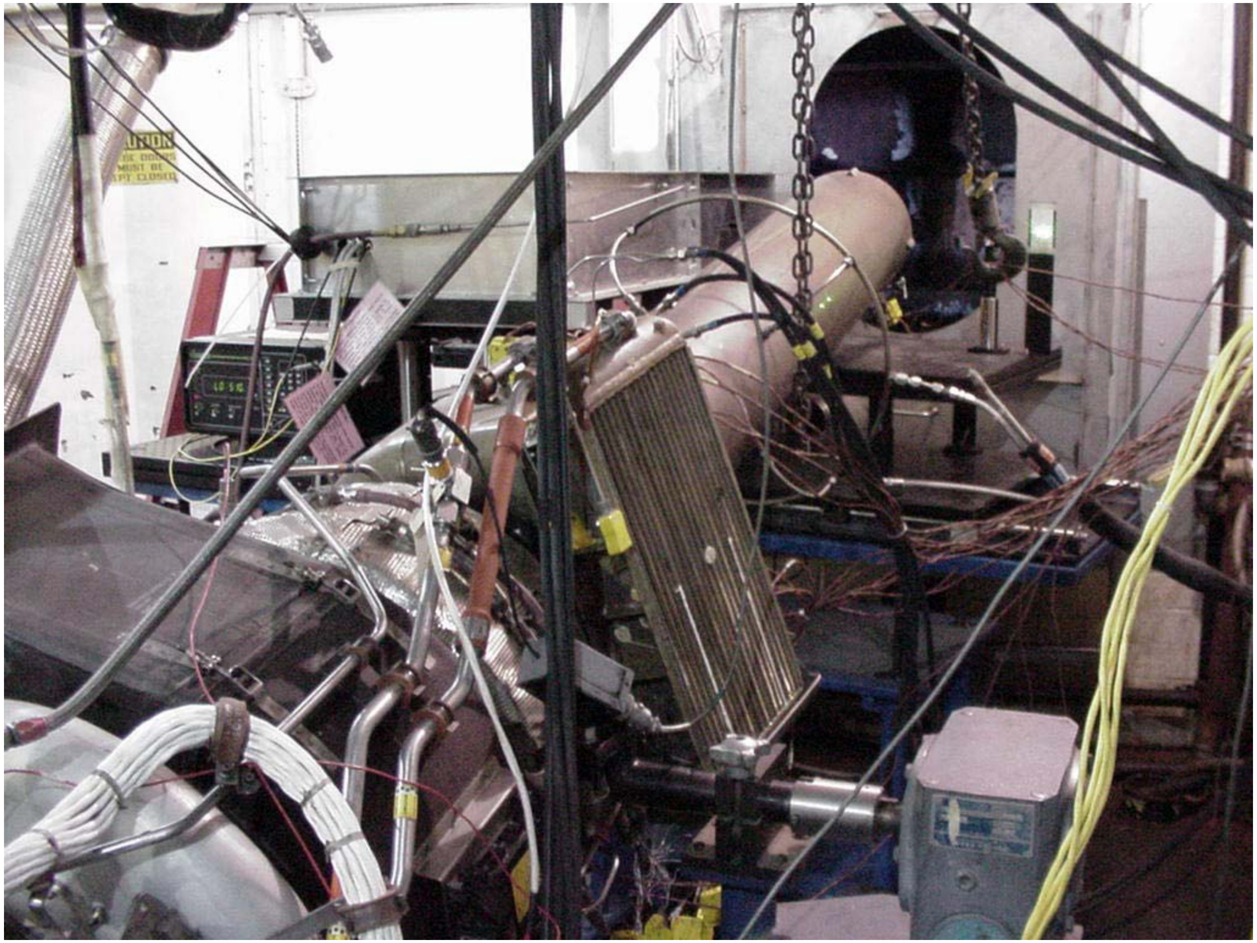


Theory vs. Experiment: 100 ppm NO, 2.4 kPa in Gas Cell

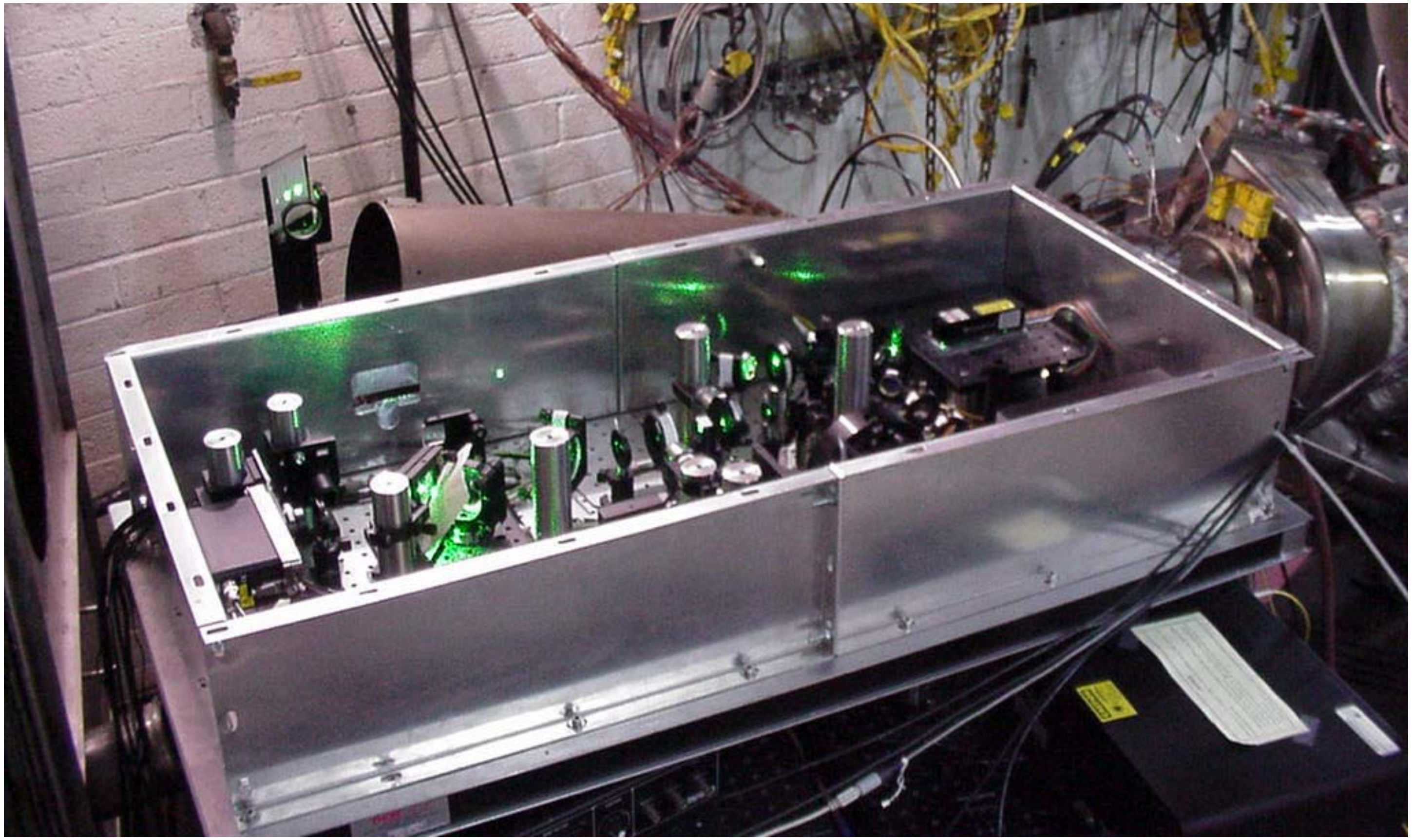


No.	Line
1	$P_2(4)$ and $^PQ_{12}(4)$
2	$P_2(3)$ and $^PQ_{12}(3)$
3	$P_2(5)$ and $^PQ_{12}(5)$

Field Demonstration: Honeywell Gas Turbine Engine



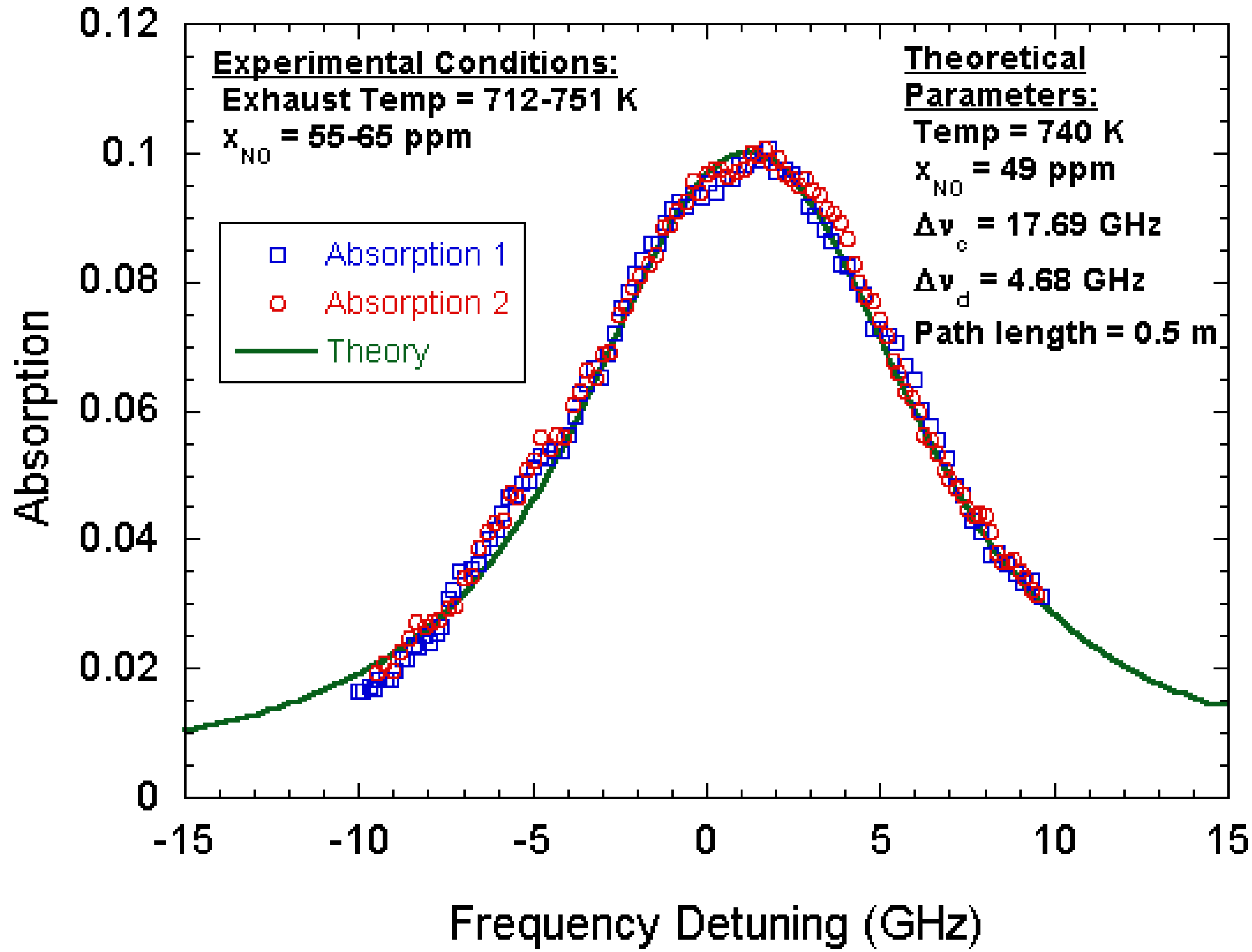
Field Demonstration: Honeywell Gas Turbine Engine



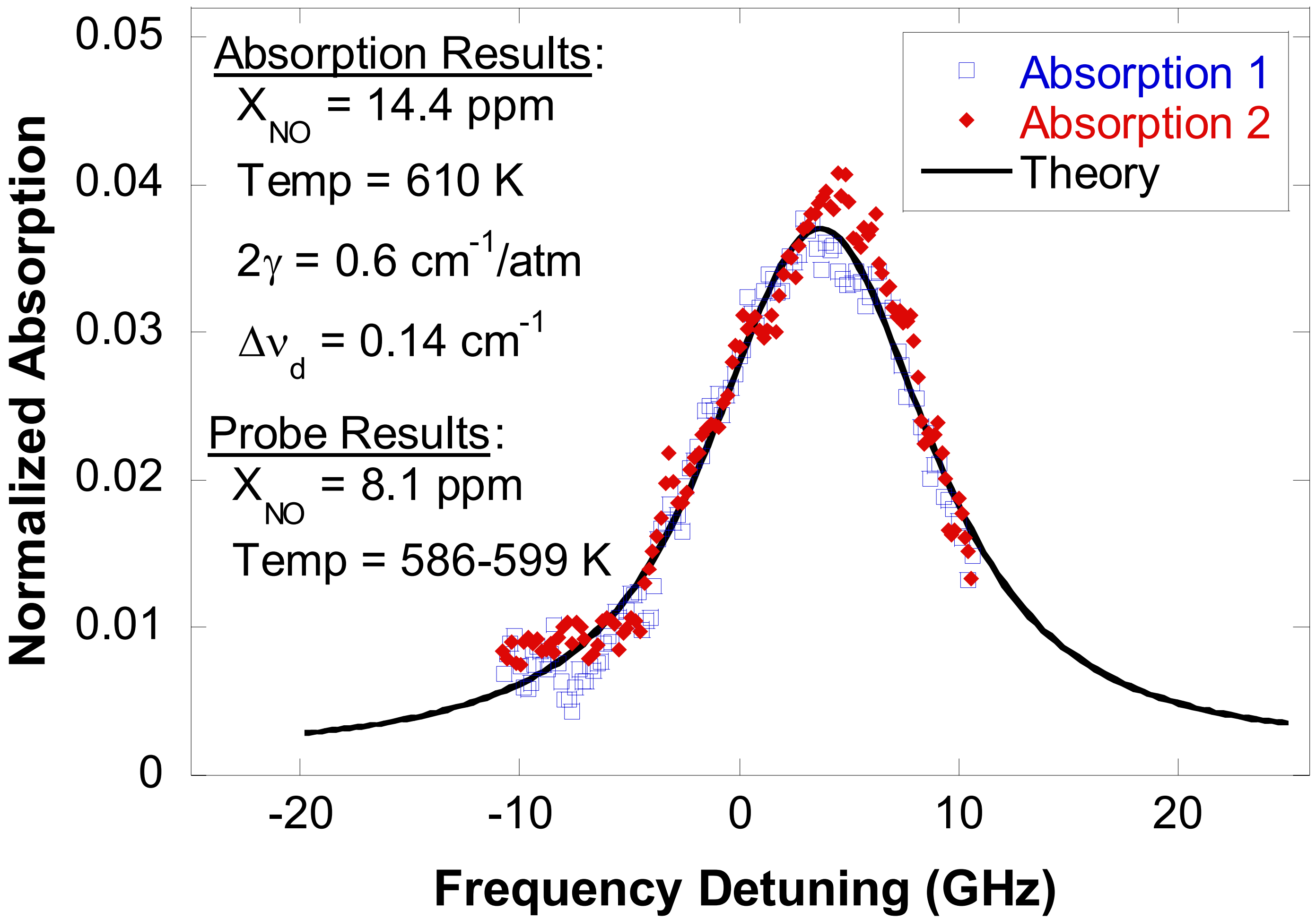
Field Demonstration: Honeywell Gas Turbine Engine

- Sensor system operated remotely because of high level of noise and vibrations in test cell
- Compared results with chemiluminescent analyzer
- Tuned laser to probe $P_2(10)$ and $^{P}Q_{12}(10)$ transition of NO

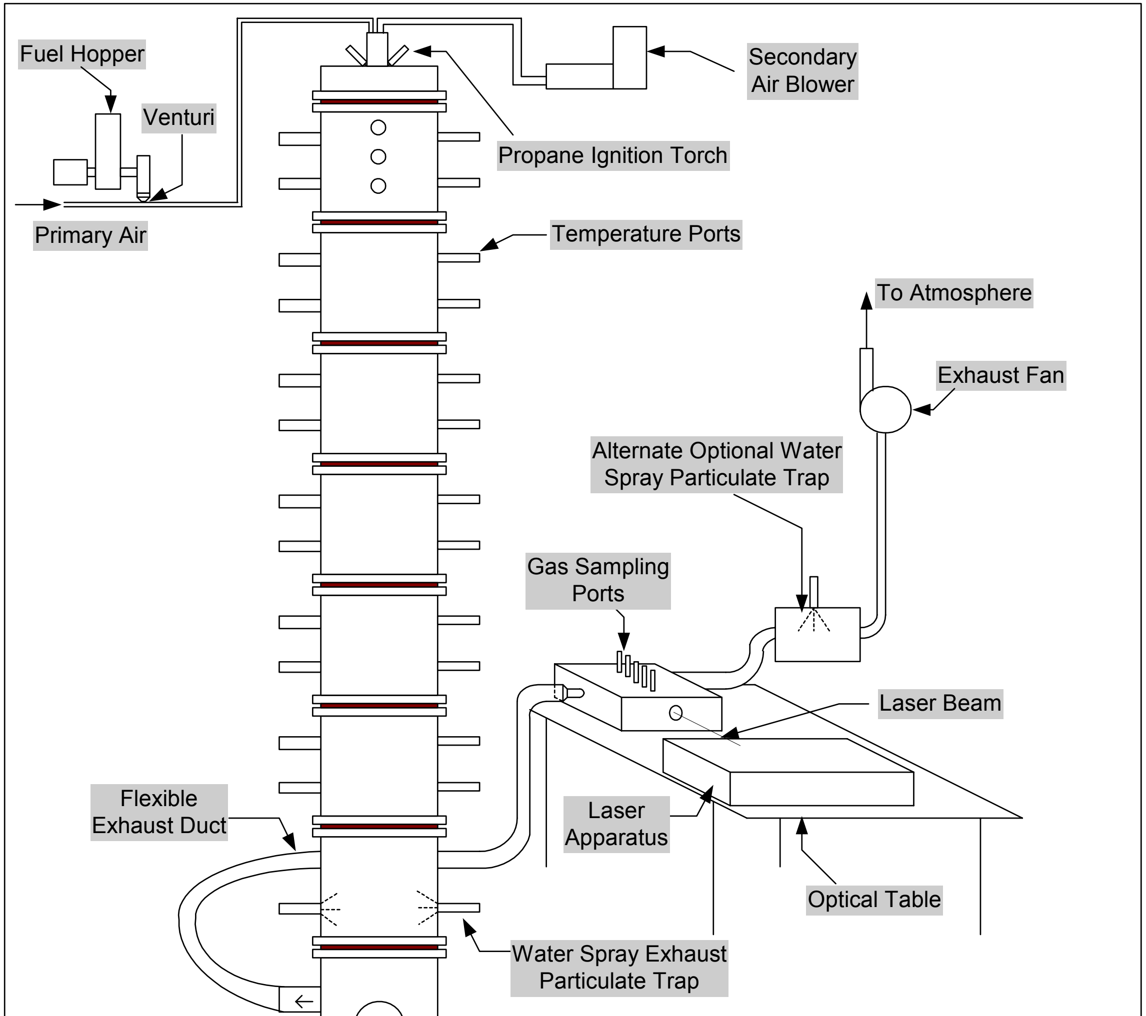
Gas Turbine Measurements: High Load Condition



Gas Turbine Measurements: Low Load Condition

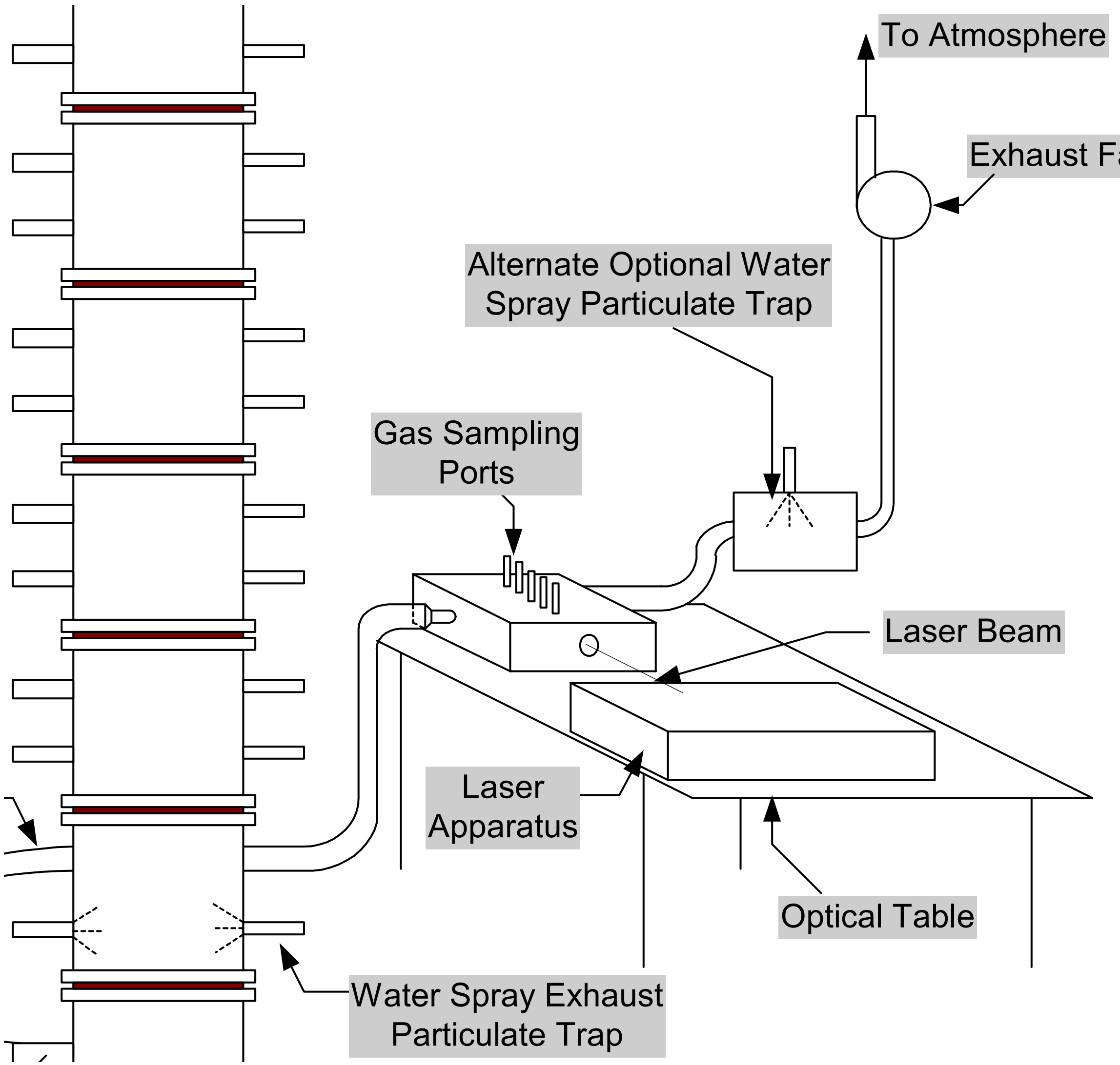


Modified Boiler Burner Facility

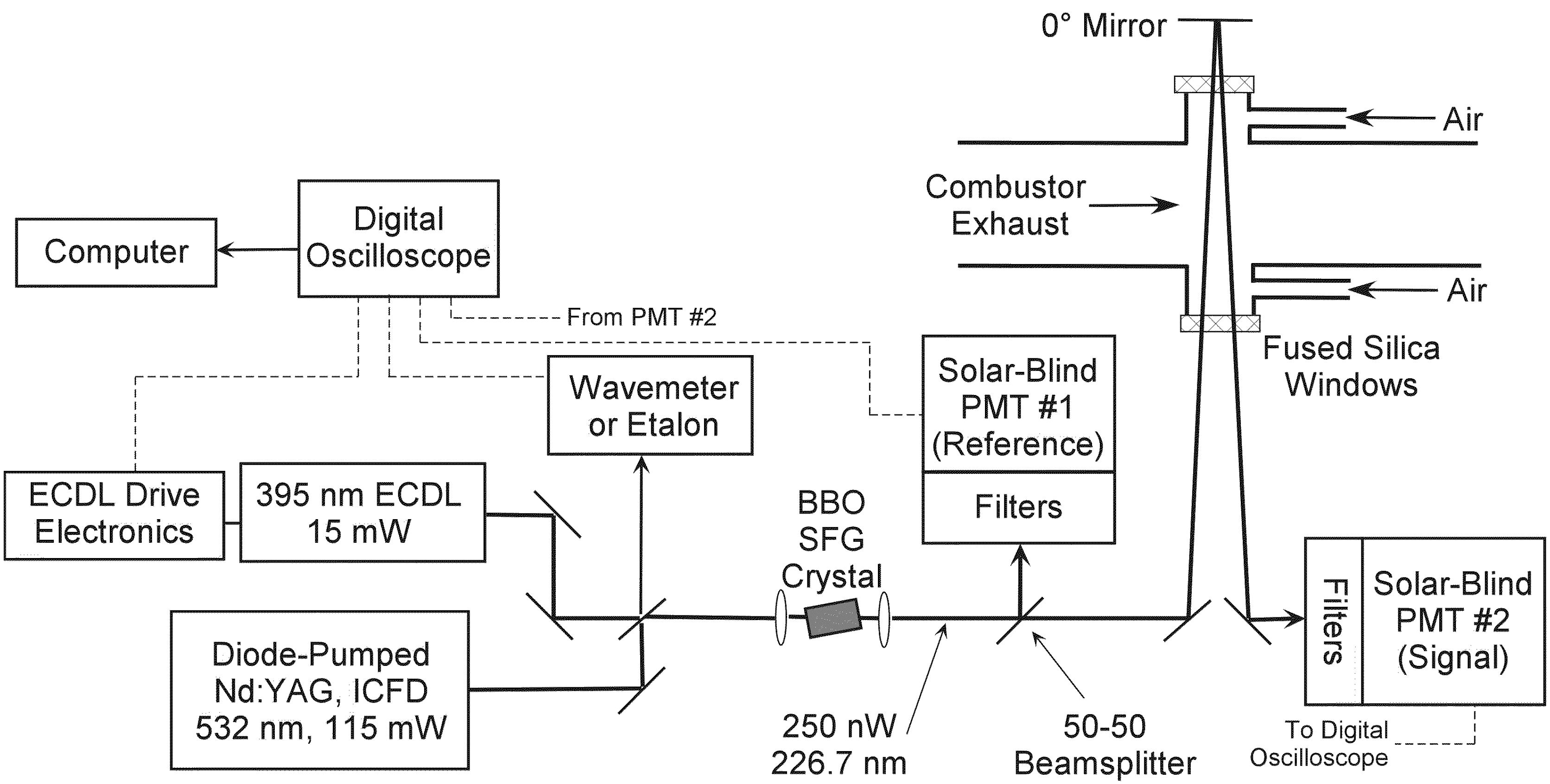


SCHEMATIC SKETCH OF TAMU 30 kW_t (100,000 Btu/hr) BOILER BURNER FACILITY MODIFIED FOR LASER MEASUREMENTS

Modified Boiler Burner Facility



NO Measurements in Particle-Laden Exhaust Flow from Coal Combustor



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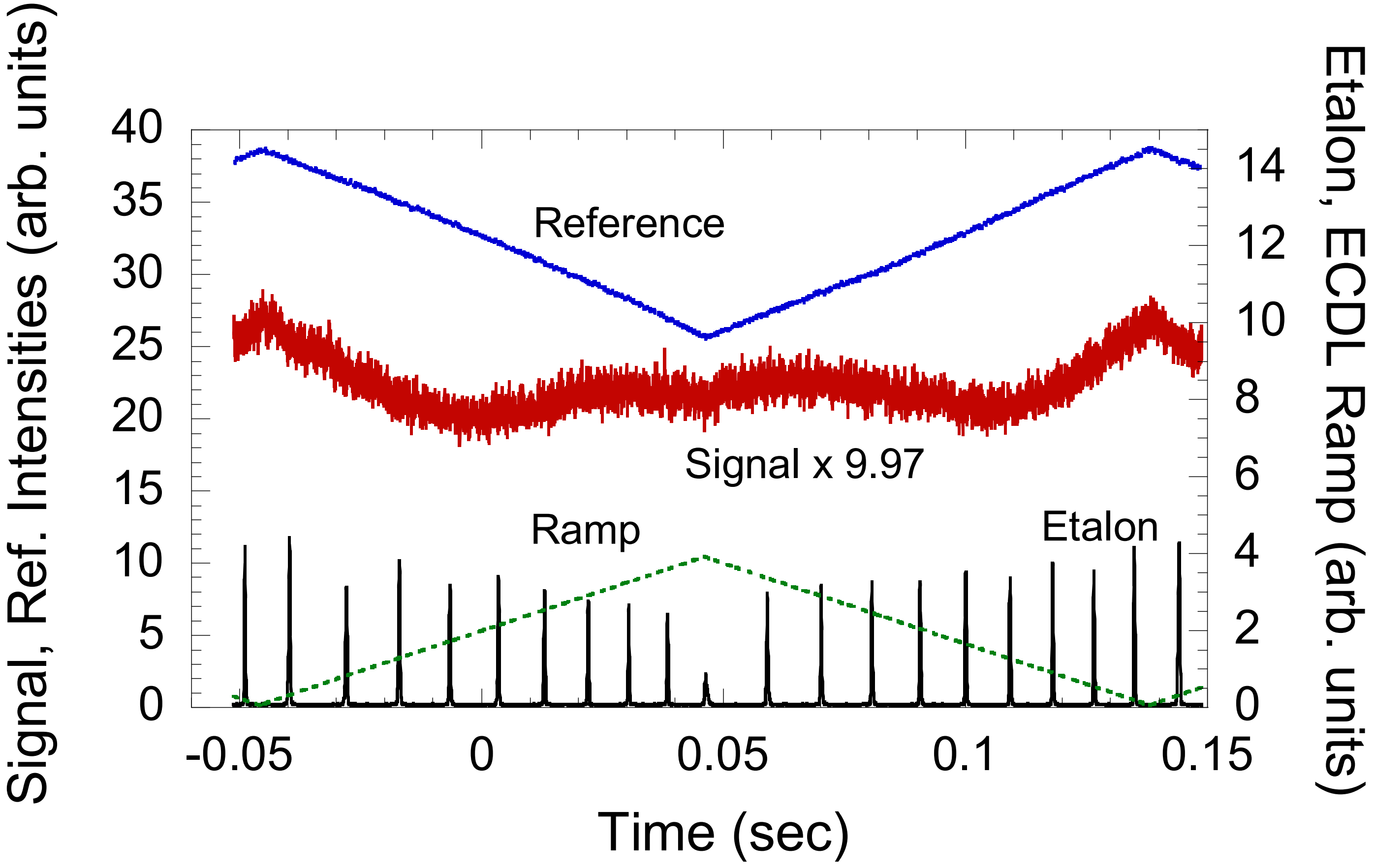

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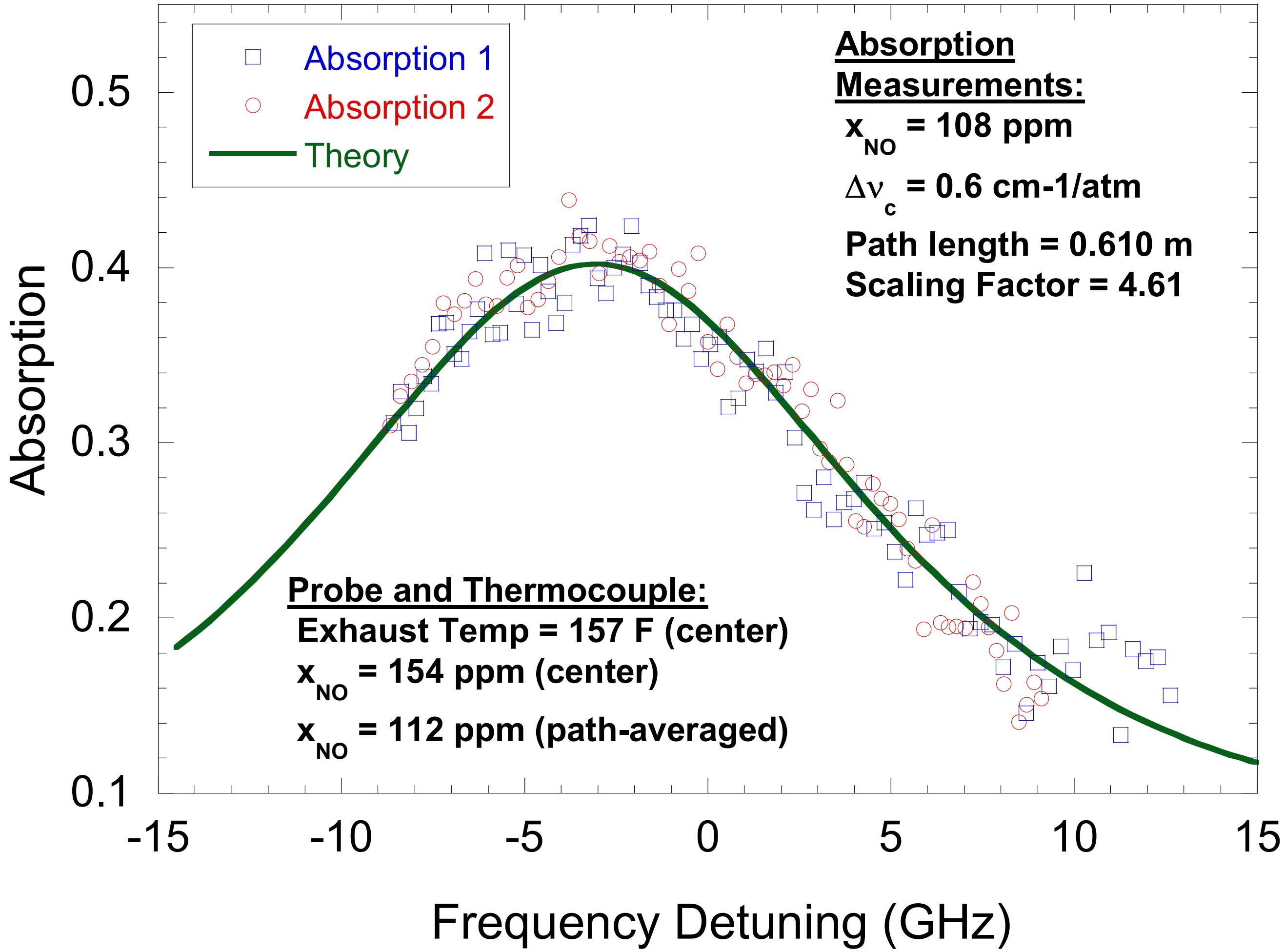
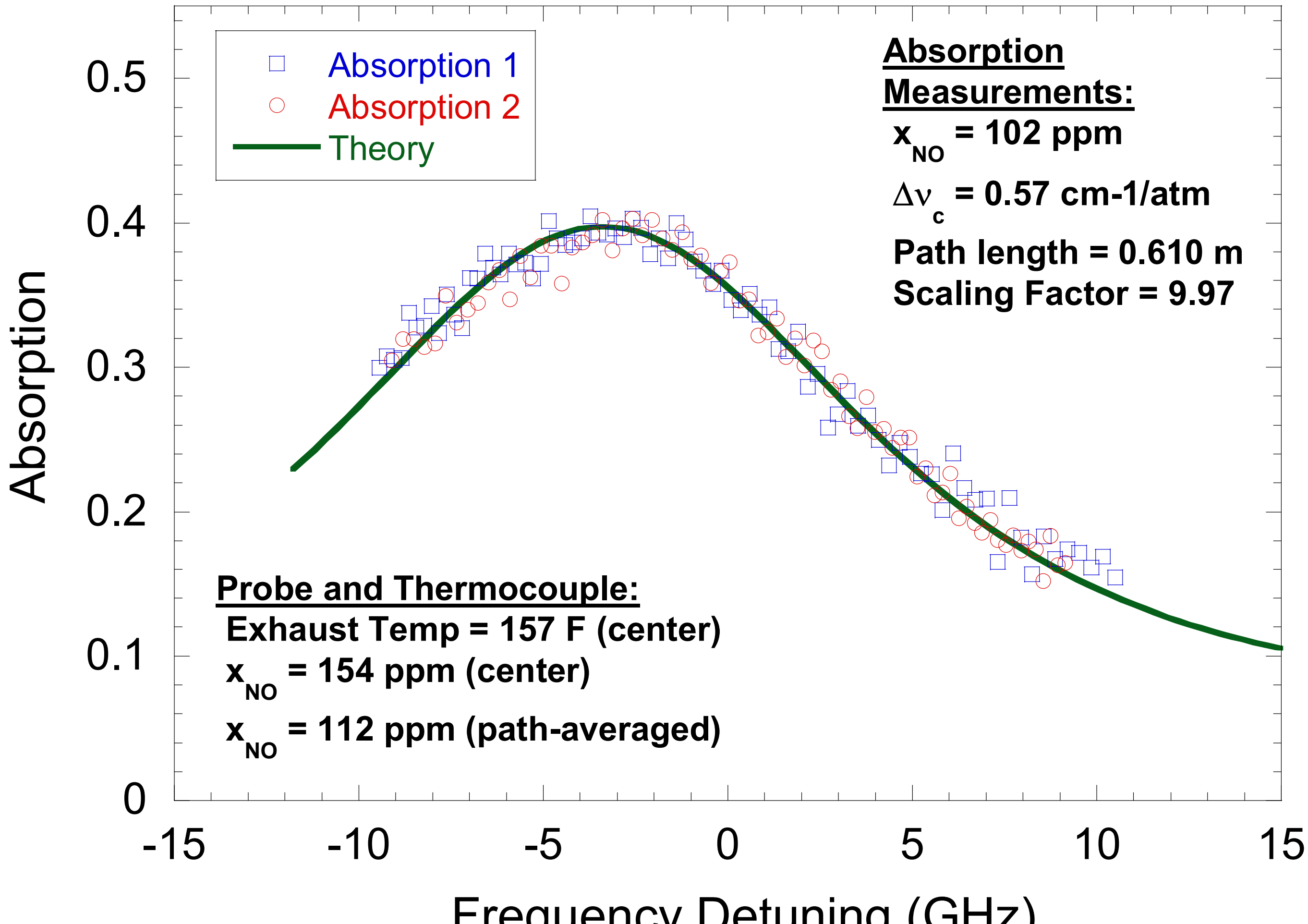


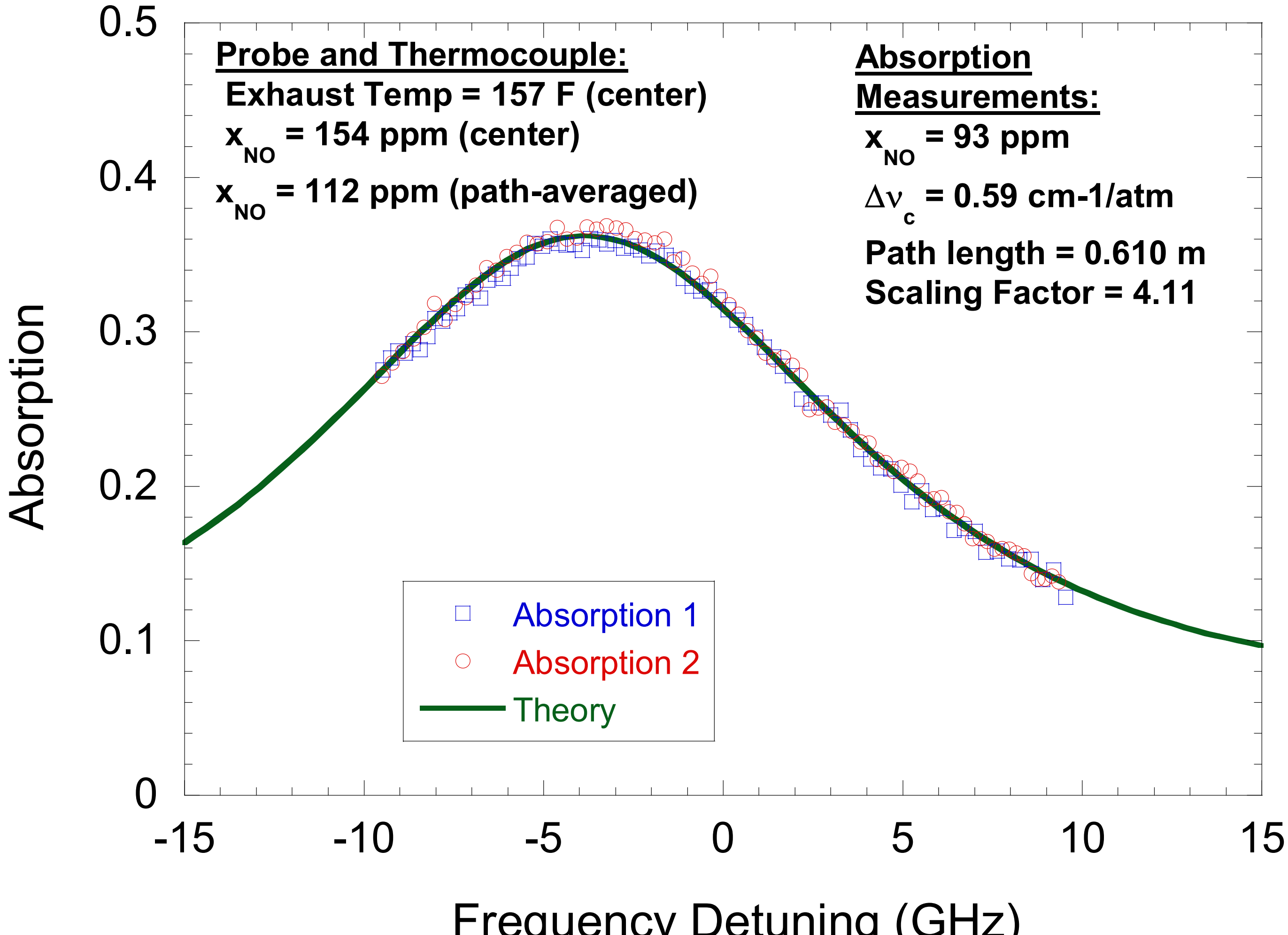
Single Sweep

NO Measurements in Particle-Laden Exhaust Flow from Coal Combustor



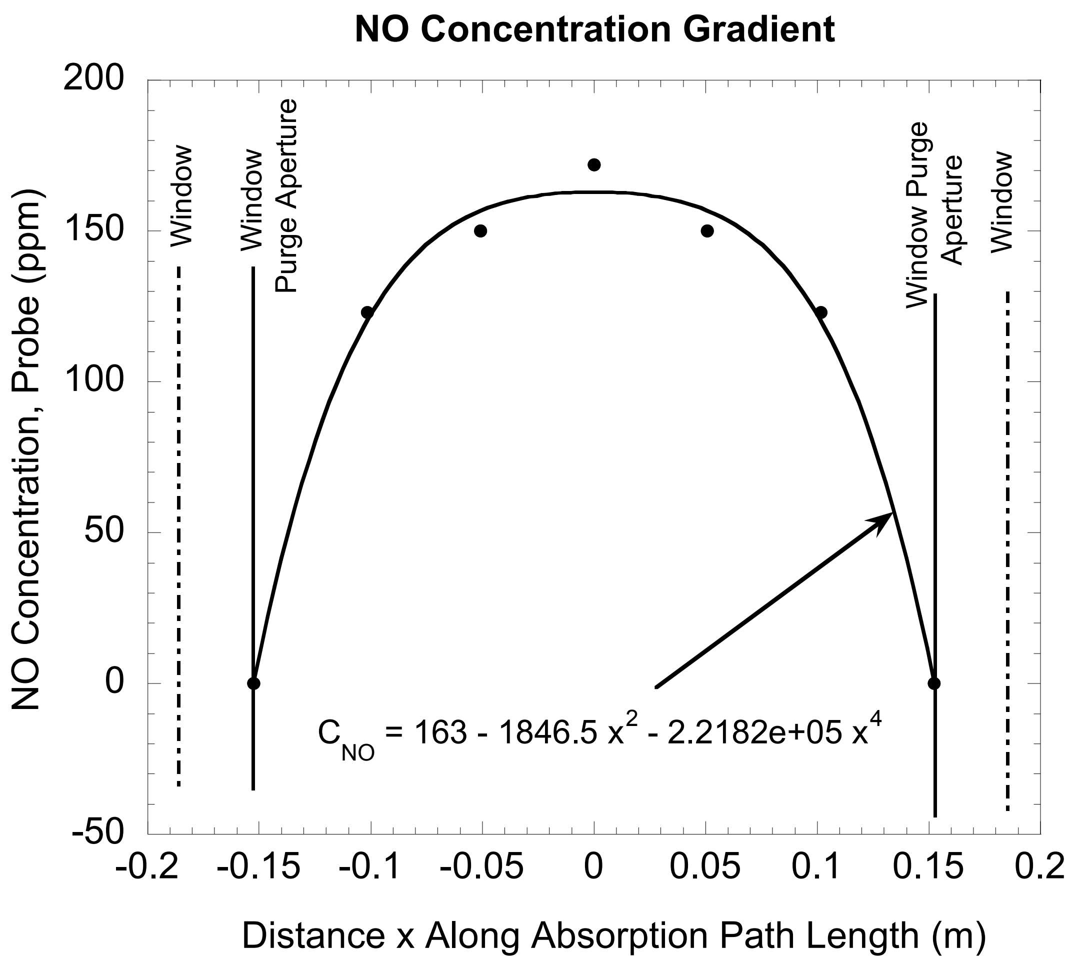
8 Sweeps

NO Measurements in Particle-Laden Exhaust Flow from Coal Combustor



32 Sweeps

Spatial Profile of NO Concentration in Particle-Laden Exhaust Flow



NO measured by probe sampling and electrochemical cell analysis at five different spatial locations along absorption beam path.

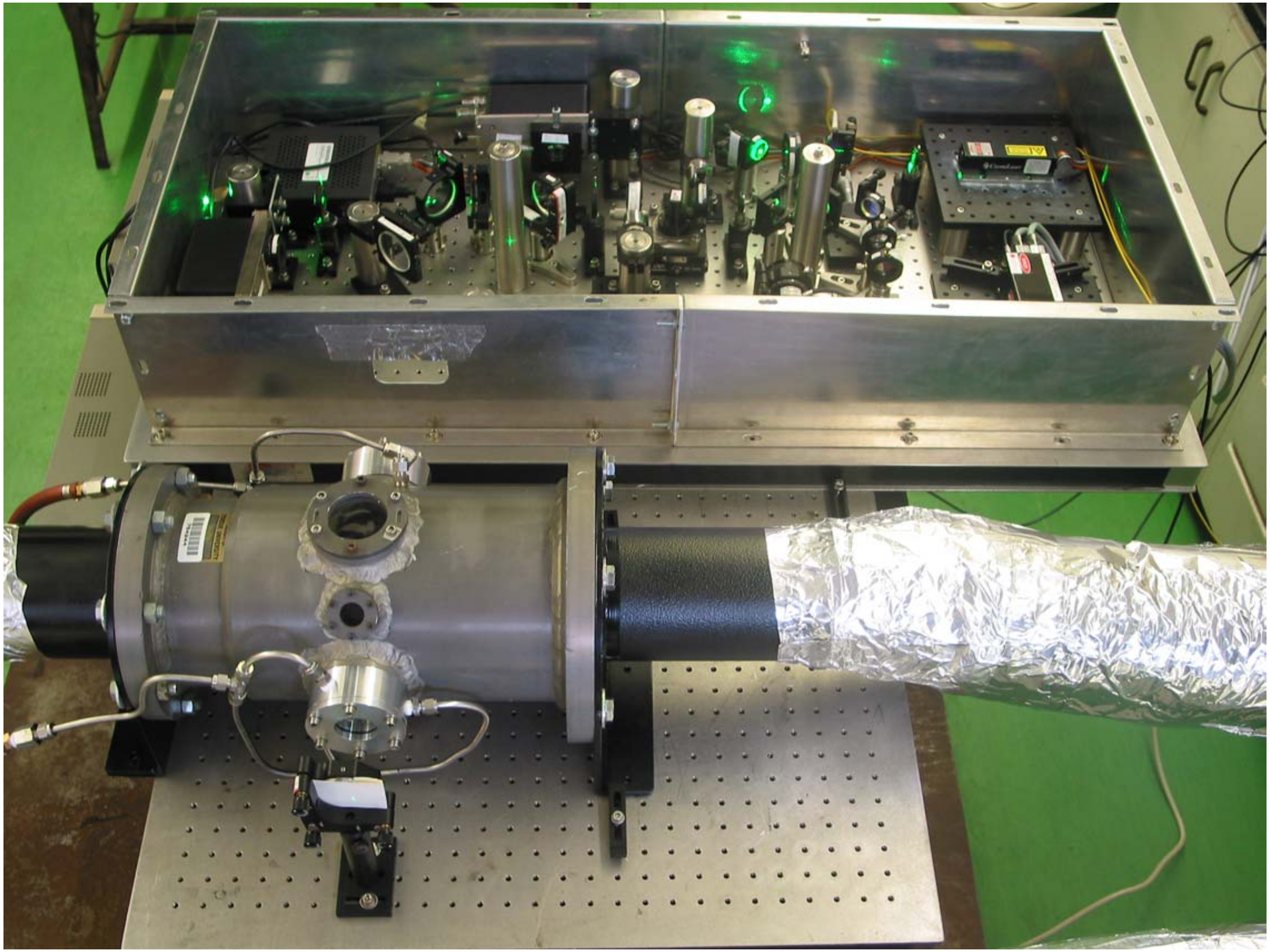
Conclusions

- New Sensor for NO Applied in TAMU Boiler Burner Facility
  - Measurements were performed successfully even with severe (> 1% transmission) attenuation of the ultraviolet beam
  - NO ultraviolet absorption measurements were in good agreement with probe measurements
  - Single-sweep, 0.1 sec measurements demonstrated, data rate limited by mechanical tuning of the ECDL

Future Work

- Increase Tuning Range and Tuning Rate of Sensors – Second Set of NO Sensor Measurements in Progress
  - Incorporate new ECDL from Sacher Laser with 90 GHz mode-hop-free tuning range
- Develop Mid-Infrared Sensor for NH_3 for Optimization and Control of Thermal DeNox Process
  - Mid-infrared NH_3 sensor will be very similar to mid-infrared CO sensor that we have developed
- Decrease Total Acquisition Time by Improving Processing and Acquisition Routines

Second Set of NO Measurements



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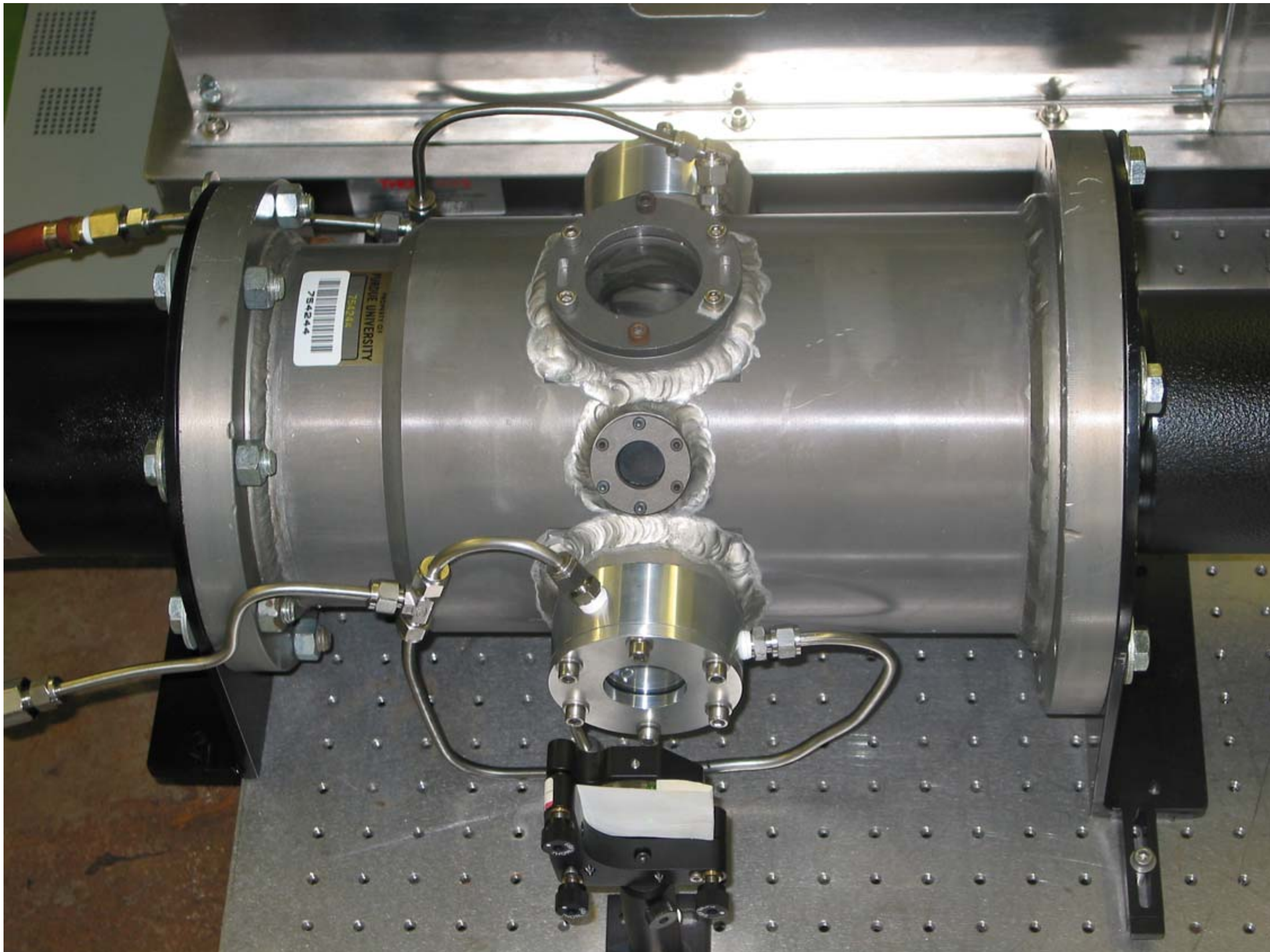
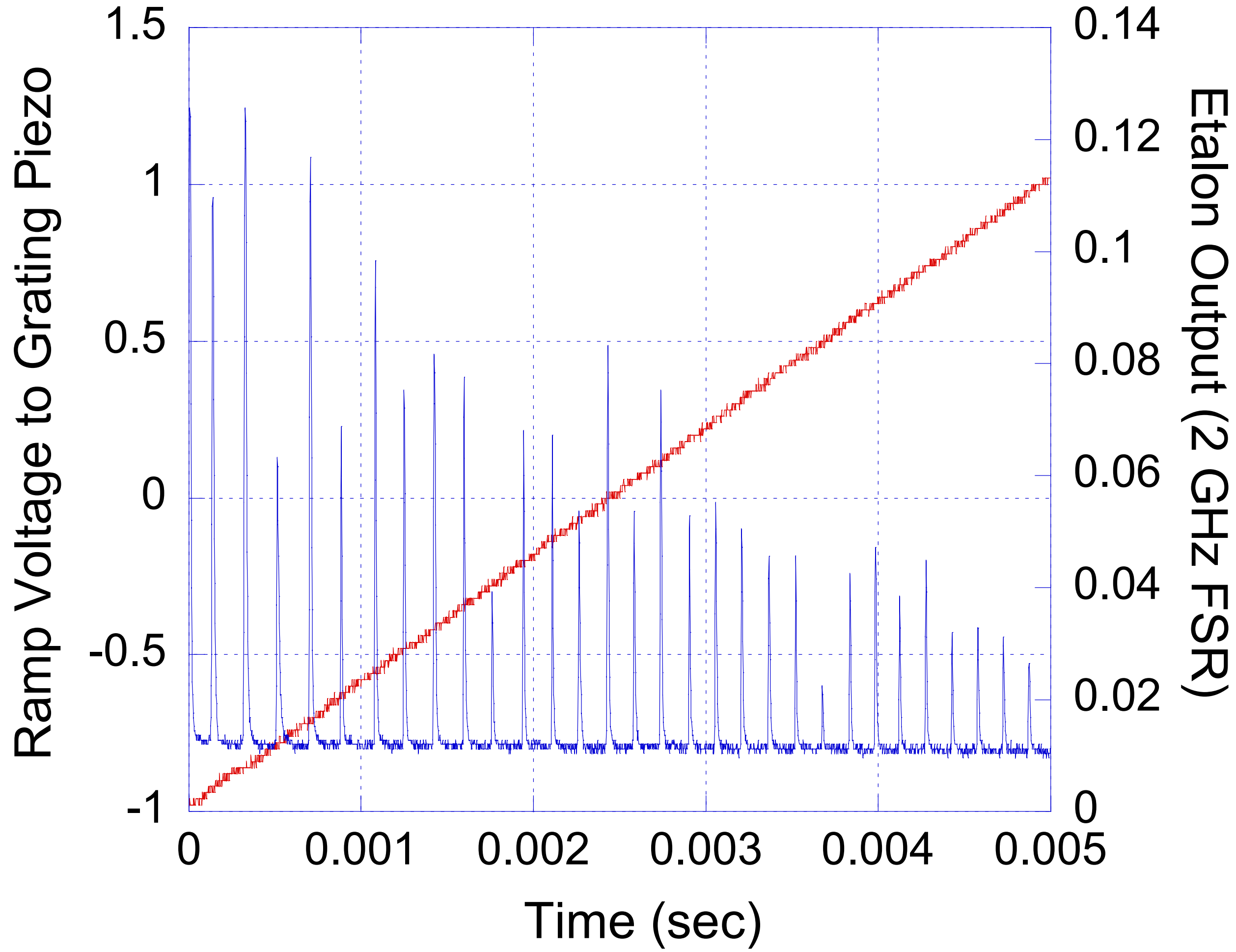
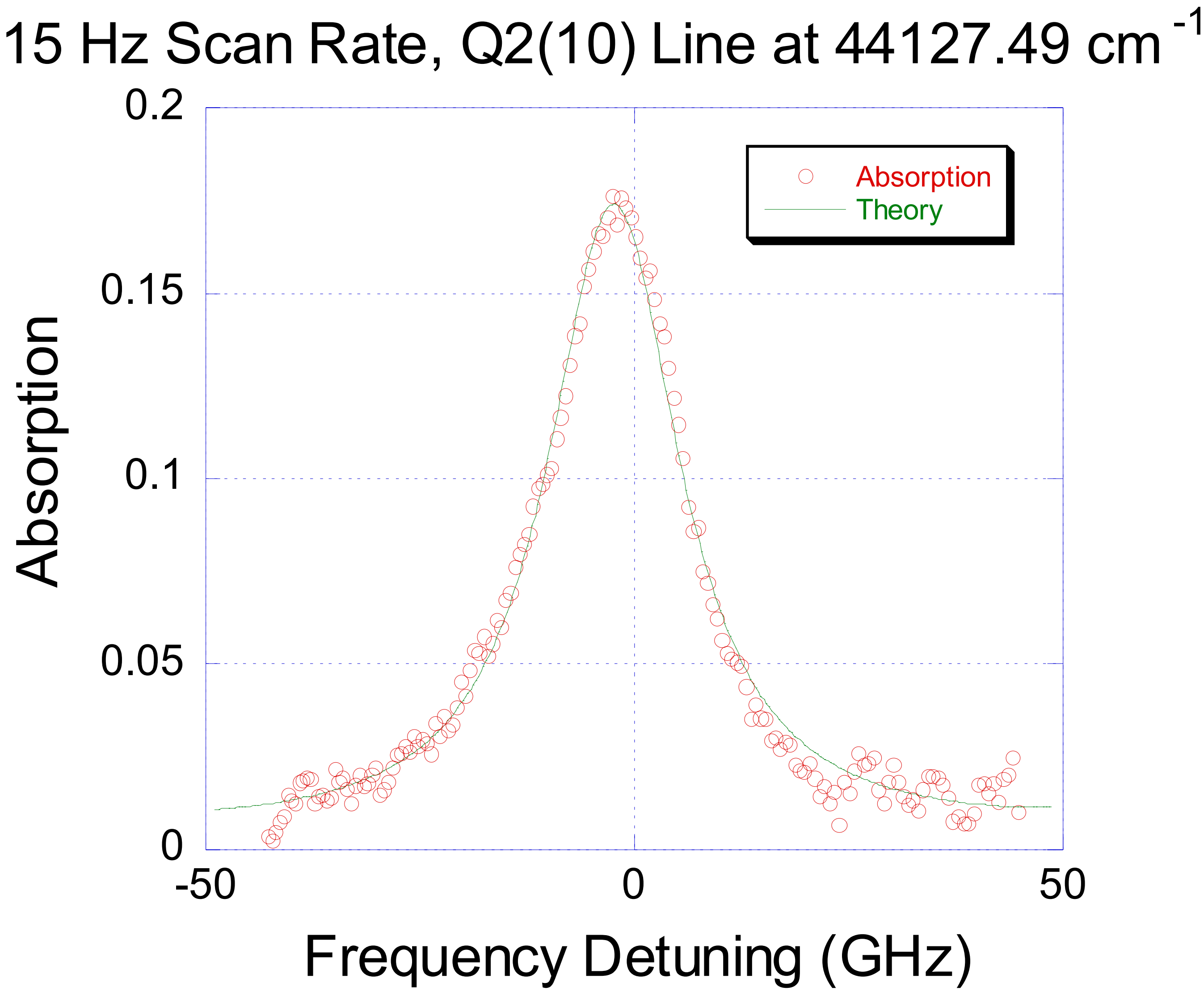


ECDL with Extended Mode-Hop-Free Tuning

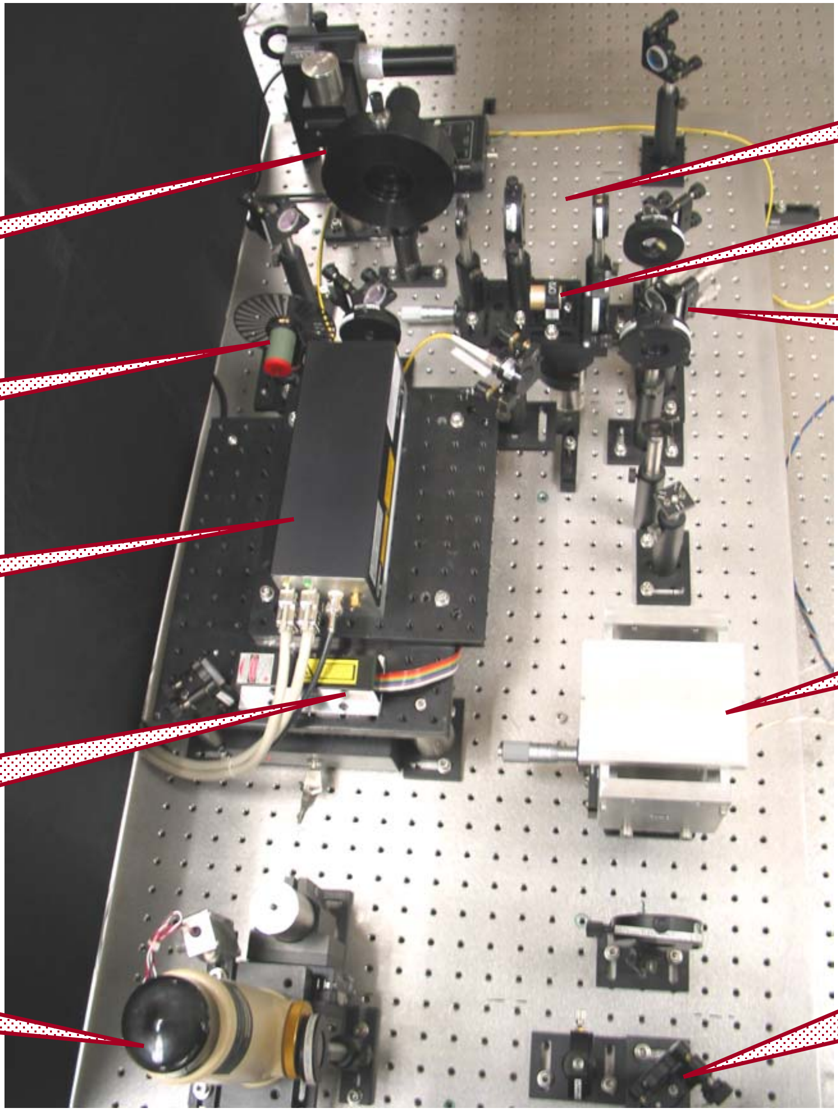


New 395-nmECDL with mode-hop-free tuning range up to 90 GHz, can be scanned at rates up to 1 kHz.

NO Absorption in Gas Cell with New ECDL



NH_3 Sensor System



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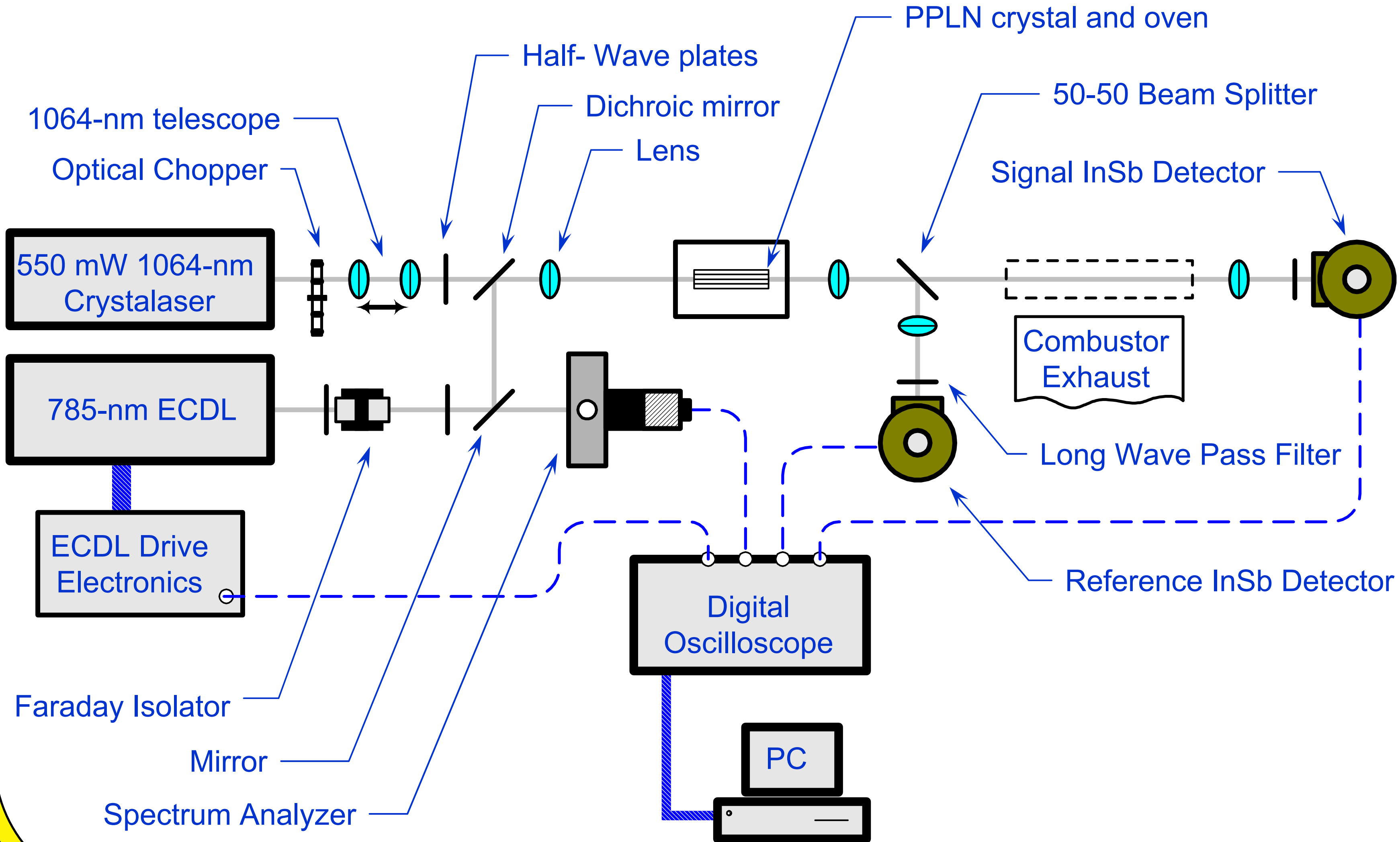
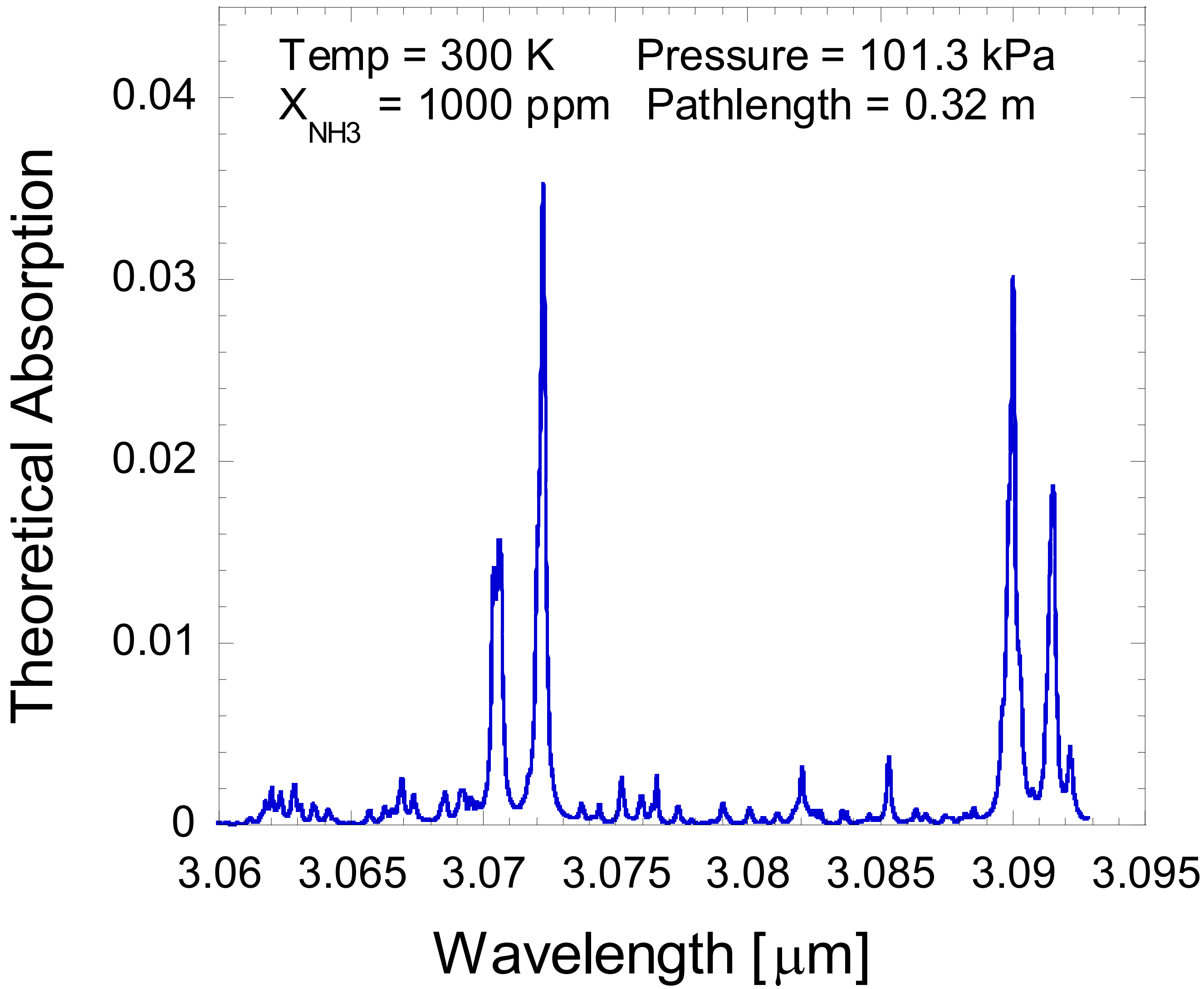
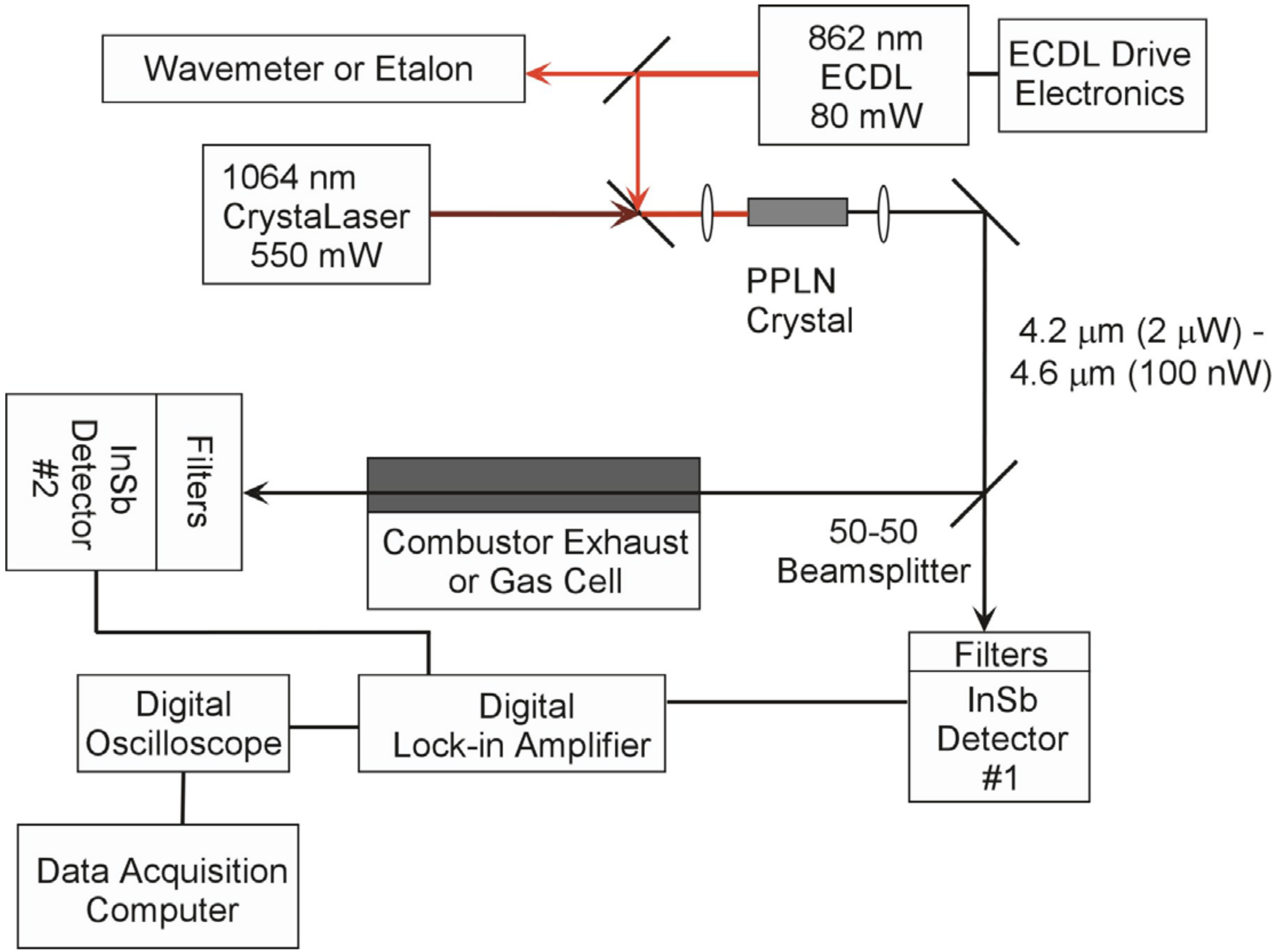


Theoretical NH_3 Spectrum



CO Sensor System



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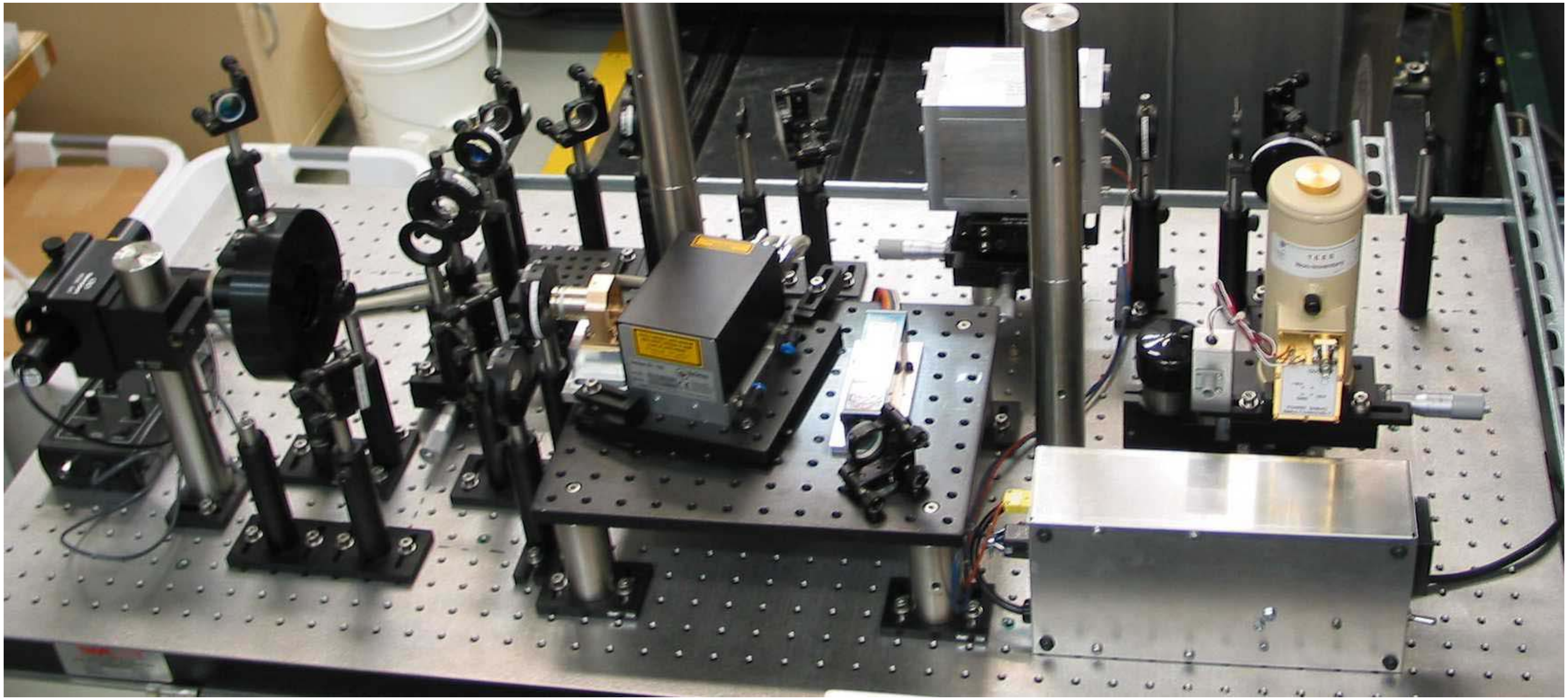

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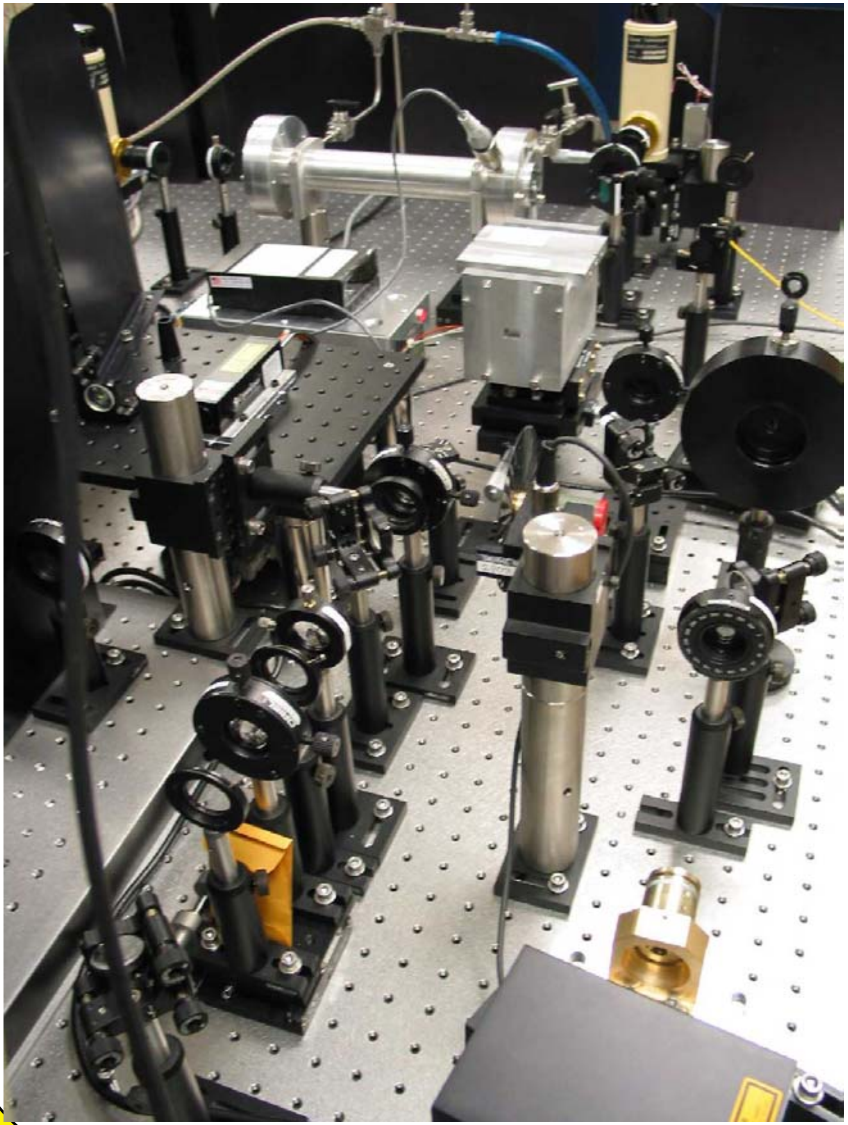
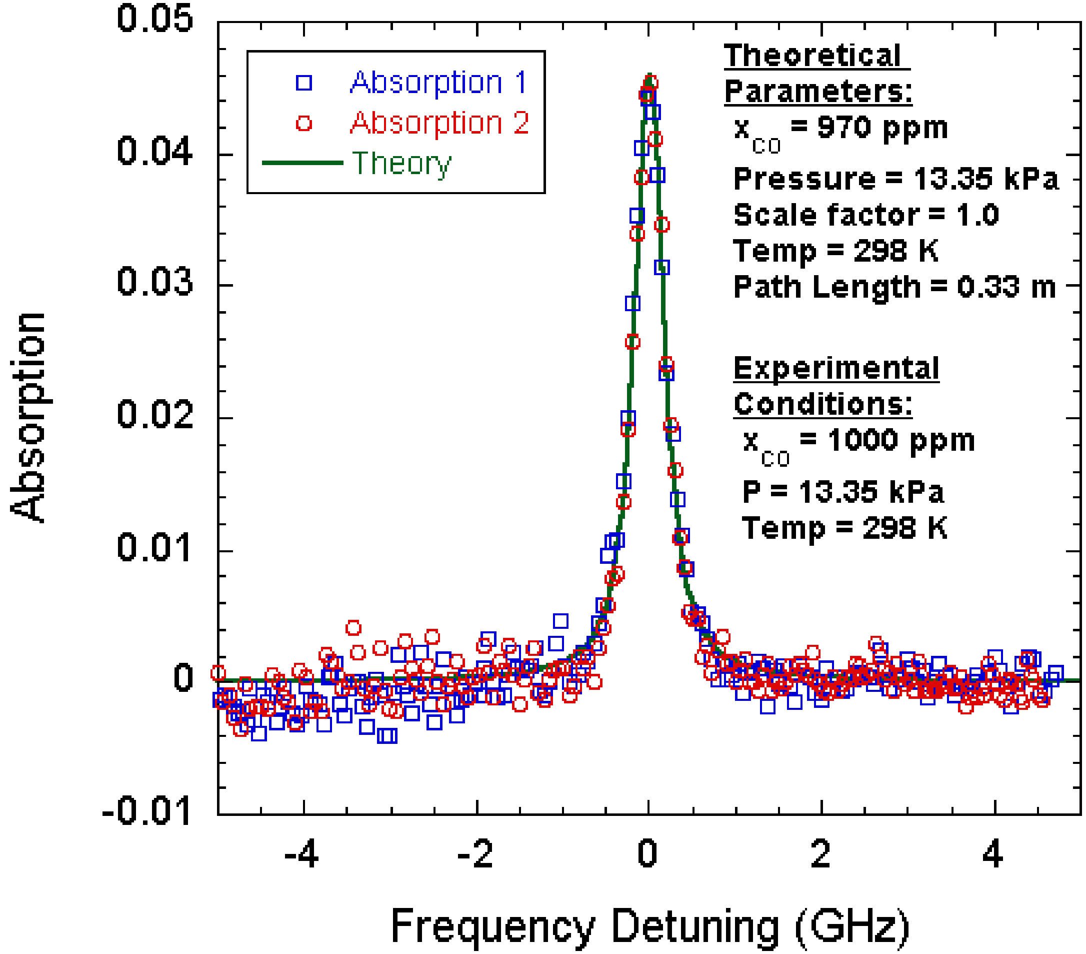


Laboratory Gas Cell Measurements: 1000 ppm CO at 13.35 kPa



R(24) Transition at 2227.639 cm^{-1}